Optimal Energy Costs based on Improving Retort Process In Food Canning Manufacturing

Supawut Saredchapan, Amphawan Chaikla, Ruedee Masuchun, Thanit Trisuwannawat, and Prasit Julsereewong

Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Ladkrabang, Bangkok, Thailand
(Tel: +66-2-739-2406-7; E-mail: kjprasit@kmitl.ac.th)

Abstract: This paper presents the minimization of the energy costs based on energy saving for industrial retort process of canned food. The approved proposed method is related the optimal steam or hot water flow control to achieve desired temperature of retort process. The smooth response and zero steady state error can be also achieved. The performances of the proposed control technique were observed using a small tuna canned food plant in Thailand as an illustrative example. The experimental results are given to support the saving in energy costs and some benefits of the proposed technique.

Keywords: energy costs minimization, retort process, temperature control, pressure control

1. INTRODUCTION

The food processing industry is the consequence of Thailand's extensive agriculture. Canned food processing is responsible for most of the past growth in the agro-industry. Products include fruits and vegetables, tunas, pineapples and seafood. The combined export value for these four items in 1998 was Bt 89.6 billions (23% of all prepared food exported) [1]. After the calamitous financial crash during 1997, Thailand's existing food processing industries have been in a period of consolidation and industrial upgrading. There are several characterization, such as

- Greater recognition and need to confirm to global standards and practices
- Using new methods of preservation
- New packaging materials and techniques
- Process technology upgrading
- Automation of production processes for improved throughput and reduced contamination

to become more competitive in the international market.

The energy cost minimization is one of the most important problems to be solved [2]. Accordingly, there has been much effort to reduce the dissipated energy of industrial process [3-5]. The purpose of this paper is to present a technique to minimize of the energy costs based on energy saving for industrial retort process of canned foods.

Usually, industrial sterilization retorts work at a constant temperature during a certain time and then cans are cooled using water. The relation time-temperature of this procedure can be optimal with state constrains [6-7]. However, the aim of the retort process of canned food is to reach the sterilization with respect to the most unyielding microorganisms damaged. Therefore, it is important to secure the food sterilization without detriment of the quality. In this paper, an approved method for optimal steam or hot water flow control is presented to achieve target temperature of retort process. The proposed control technique is based on the look-up table in combination with the PID control to set the appropriate opening position of steam control valve. In addition, the smoothness of response and zero steady state error can be also achieved.

The small tuna canned food plant, Keat Chareon Foods Co., LTD, Thailand, was studied as an illustrative example. The experimental results demonstrating the optimal energy costs based on energy saving for industrial retort process and some benefitsl of the proposed technique are obtained.

2. RETORT PROCESS

2.1 Basic concept of retort process

In batch retort process (in-can sterilization) [8], foods to be sterilized is first filled and hermetically sealed in rigid, flexible, or semi-rigid containers such as metal cans, glass jars, retort pouches, or plastic bowls. It is then placed within steam retort, large industrial-sized pressure vessel or cooker, as shown in Fig.1. The horizontal still retort is widely accepted type for small and medium food canning manufacturing in Thailand.

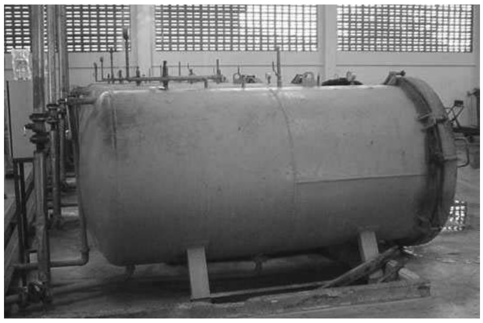

Fig. 1 Horizontal still retort

The relation time-temperature of the retort process is shown in Fig.2. During venting period, the retort is filled with containers to be sterilized, the retort door is closed tightly and the air is then replaced by the hot steam under pressure to achieve temperatures above the atmospheric boiling point of water. Next during cooking period, the canned foods are then heated under steam pressure at the temperatures of 116-121^{o}C (240-250^{o}F). The amount of time needed for processing is different for each food, depending on the food's acidity, density and ability to transfer heat. After the containers have been exposed to the sterilizing temperature for sufficient time to achieve the desired level of sterilization, the steam control valve is shut off and the cooling water is then brought in to cool the containers and reduce the pressure, thus ending the process in cooling period.

Once the retort pressure has brought back to atmosphere, the door can be opened, and the processed containers are removed for labeling, case packing, and warehousing to await distribution to the market place.

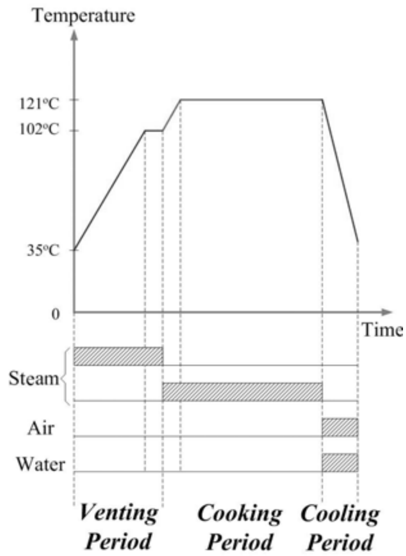

Fig. 2 The relation time-temperature of retort process

Processing conditions are chosen to minimum needed to ensure that foods are commercially sterile, yet retain the greatest flavor and nutrition. All processes must be approved by the Food and Drug Administration (FDA). In addition, most processed foods are closely monitored, using a system called Hazard Analysis and Critical Control Point, or HACCP. A HACCP system identifies areas of potential contamination within the food process and builds check points to ensure that highest possible safety standards are maintained at all times.

2.2 Principle of temperature control of retort process

Temperature control is important because the objective of the sterilization process is to produce a condition called "commercial sterility" [9]. The recommended sterilization processes are not designed to kill all microorganisms in canned foods. The still retort sketched in Fig.3 is used to sterilize canned food. The objective is to maintain the sterilization temperature at its desired value or set point in the presence of variations of the steam fluid flow. The still retort is heated by steam spraying through a pipe. A proportional-integral-derivative (PID) controller is used to control the temperature in the still retort by manipulating the steam valve position.

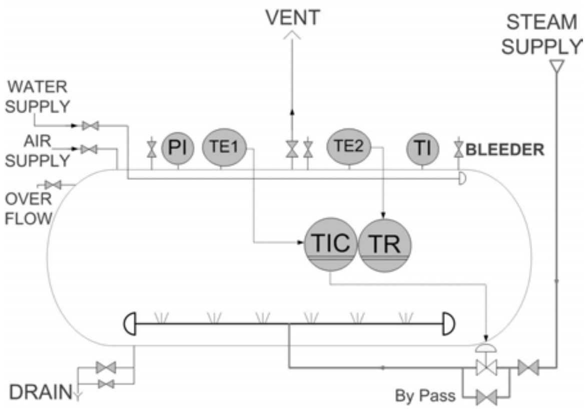

Fig. 3 Temperature control loop of still retort

The temperature control scheme works as follows: the temperature and pressure of still retort are monitored with a thermometer (TI) and pressure gauge (PI), respectively. The still retort temperature or controlled variable is measured with a sensor RTD (TE1). The temperature-proportional measured signal is sent to the controller (TIC) where it is compared to the set point. The function of the controller is generated an output signal or manipulated variable, on the basis of the error or difference between the measurement and the set point. The controller output signal is then connected to the actuator of the steam control valve through a current-to-pressure transducer (I/P). The function of the valve actuator is to position the valve in proportional to the controller output signal. Thus the steam flow is a function of the valve position.

2.3 The proposed technique

This paper proposes the optimal steam flow rate control during venting and cooking periods by technique called "look-up table" in combination with PID controller. Look-up table technique develops feed forward control within the calculation of the required value of the manipulated variable to maintain the controlled variable at its set point. If the calculation is performed correctly, the controlled variable should remain undisturbed [10]. The proposed technique as shown in Fig.4 can be explained as follow.

From the temperature control loop in Fig. 3, the still retort temperature measured signal (pv) is sent to the controller (TIC) where it is compared to the set point (sp). The manipulated variable (mv) is generated by the controller, which is based on the magnitude of error (e) or difference between the measurement and the set point. If the magnitude of calculated error is greater than the preset value ($\varepsilon = \pm 10\%$), the lookup table technique is applied to control. Otherwise the temperature control will be operated by PID mode.

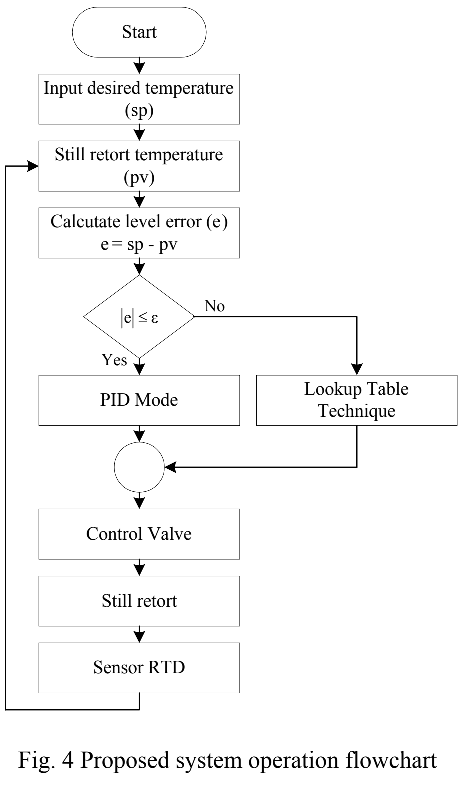

Fig. 4 Proposed system operation flowchart

At the begining of venting period, the position of steam valve is 80% opening for energy saving, when the retort temperature (pv) reaches the desired temperature or set point (sp), the lookup table technique is applied to set the appropriate percent open of steam control valve. After that the retort temperature during cooking period is controlled using the PID control mode.

3. EXPERIMENTAL RESULTS

The performances of the proposed control technique for retort process were observed using the small tuna canned food plant, Keat Chareon Foods Co., LTD, Thailand, as an illustrative example. The experimental still retort is shown in Fig. 5, which uses the steam control valve as equal percentage type. The comparison result in circular chart between temperature controlled using the proposed technique and using only PID control, is shown in Fig. 6. It is clearly seen that the proposed control technique provides the better performances.

The basic inherent flow characteristics of various control valves are shown in Fig. 7, which are determined by the valve plug configurations or cage port configurations. The inherent-flow characteristic defined as the relationship between the percentage of valve flow coefficient value (%Cv) and the percentage of valve position or valve travel, where the maximum value of Cv is about 25. From experimenting, the 80% opening position of steam valve is the appropriate value for energy saving without product quality detriment.

Fig. 5 Experimental still retort

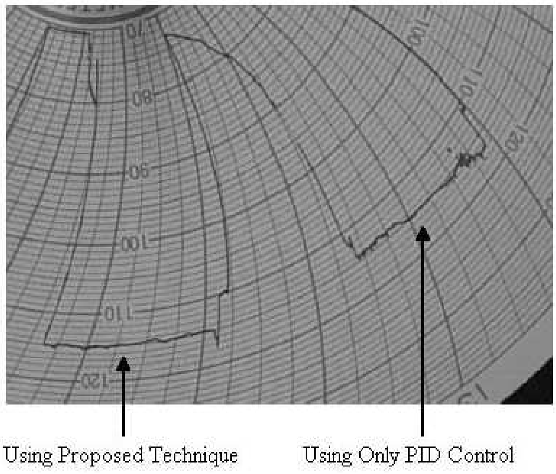

Fig. 6 Temperature responses of retort process

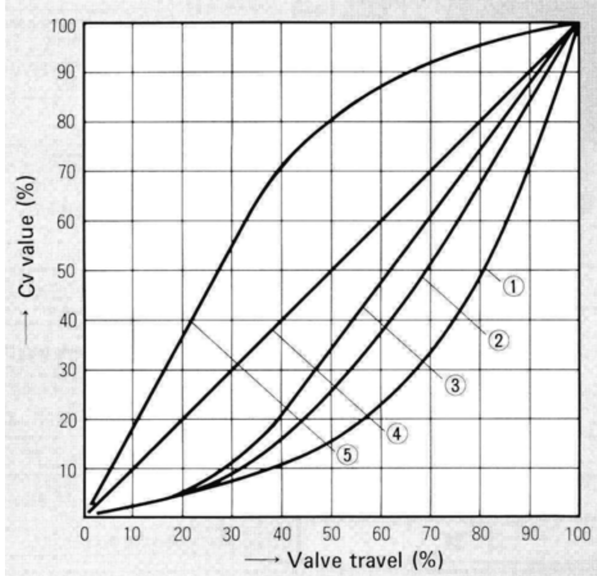

Fig. 7 Inherent flow characteristics
(1) Equal percentage
(2) Parabolic
(3) Modified parabolic
(4) Linear
(5) Quick opening

4. OPTIMIZATION RESULTS

In order to calculate the energy saving, Nakakita's Cv formula for steam fluid [11], which is based on the widely accepted formula of Fluid Control Institute (FCI), is applied as

$$Cv = \frac{W}{11.7 \times p_1} \times k \qquad (1)$$

where W is the maximum flow rate (kg/hr)
p_1 is the inlet pressure (kgf/cm^2 abs)
k is the correction coefficient to superheat

In this paper, the assumed correction coefficient k is approximately 1 and the maximum inlet pressure of the experimental still retort is approximately 7 kgf/cm^2 abs. Based on Eq. (1), the maximum flow rate of steam W can be stated as

$$W \approx 81.9 \times Cv \qquad (2)$$

Considering the equal percentage flow characteristic in Fig. 7, the minimization of the energy costs based on energy saving can be discussed as follow:

Before the improving: the position of steam valve or the valve travel is 100%, the Cv value is 100% of the maximum Cv value, then Cv value = (100/100) * 25 = 25

After the improving: the position of steam valve or the valve travel is 80%, the C_v value is 48% of the maximum Cv value, then Cv value = (48/100) * 25 =12

The result from the proposed technique:
The decreasing of the Cv value = 25 - 12 = 13

The decreasing of the maximum flow rate of steam or the saving in steam = 81.9 * 13 = 1064.7 kg/hr = 1.0647 tons/hr

It is clearly seen that the saving in energy can be performed using the proposed technique.

The true energy costs saving based on the amount of fuel for six batches retort process (928.7 tonnage) occurred in April 2002, can be calculated as

Before the improving:
The amount of fuel $\approx$ 55.46 liter/tonnage

After the improving:
The amount of fuel $\approx$ 50.657 liter/tonnage

The result from the proposed technique:
Saving in energy costs $\approx$ (55.46-50.657)*928.7
$\approx$ 4460.55 liter/month
The fuel costs $\approx$ 7.75 Bt/liter

Total saving in energy costs
$\approx$ 4460.55*7.75 $\approx$ 34569.26 Bt/month
$\approx$ 34569.26*12 $\approx$ 414831 Bt/yr

The optimization results show that the energy costs drops to 8.66% and annual energy cost savings is about Bt 415,000.

5. CONCLUSION

This paper has described the saving energy costs of retort process in food canning manufacturing. In order to save the energy, the optimal steam flow is applied to control the target temperature. The proposed technique is based on the look-up table in combination with PID control to set the appropriate position of steam control valve. The experimental results show that the proposed technique can reduce the amount of steam during retort venting period. In addition, the smoothness of response and zero steady state error can be also achieved.

REFERENCES

[1] http://www.agrofoodasia.com/Thai_agrifood/thai_agri food.html
[2] Xinggao Liu, Yongmao Xu, Jie Zhang and Jixin Qian, "Optimal Energy Cost in Ideal Internal Thermally Coupled Distillation Columns", *Proceedings of the American Control Conference Anchorage*, AK, pp. 1502-1507, 2002
[3] S. Dunning, T. Ward, "Energy and waste saving measures for the paper and wood products industry", *Conference Record of Pulp and Paper Industry Technical Conference 1998*, pp.80 –86, Jun 1998
[4] N. Hayajawam, Y. Wakazono, T. Kato, Y. Suzuoki, and Y. Kaya, "Minimizing energy consumption in industries by cascade use of waste energy", *IEEE Transactions on. Energy Conversion*, Vol. 14, No. 3, pp. 795 –801, Sep 1999
[5] A. Canova, F. Profumo, M. Tartaglia, "LCC design criteria in electrical plants oriented to energy saving", *IEEE Transactions on Industry Applications*, Vol. 39, No. 1, pp. 53 –58, Jan/Feb 2003
[6] A. Bermudez, C. Rodriguez and A. Martinez Verela, "Two Applied Optimal Control Problems with State Constraints", *Proceedings of the 30th Conference on Decision and Control*, England, pp. 1985-1990, 1991
[7] D. Kseibat, O.A. Basir, and G.S. Mittal, "An Artificial Neural Netword For Optimizing Safety and Quality in Thermal Food Processing", *Proceeding of the 1999 IEEE International Symposium on Intelligent Control/Intelligent Systems and Semiotics*, Cambridge, MA, pp. 393-398, 1999
[8] http://www.succeed.ufl.edu/content/abe2062/modules/ Sterilization/sterilization.htm
[9] A Complete Course In Canning And Related Processes, Book III, *Processing Procedures For Canned Food Products*, 13th Edition, CTI Publications, Baltimore, MD. 1996
[10] N. Sangjeen and P. Julsereewong, "A Design of Two-mode Controller Using PC-based Lookup Table Technique and PID Control Algorithm" *ICCAS2002, Proceeding of the 2002 International Conference on Control, Automation and Systems*, Korea, pp. 412-417, 2002
[11] Nakakita Seisakusho co., Ltd, "*Nakakita Control Valve*", Catalog. No. 310-4E, 1997